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THE USE OF CHEMICAL STIMULANTS TO INCREASE GUM YIELDS IN SLASH AND LONGLEAF PINES

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INTRODUCTION

Chemical stimulation of gum flow in slash and longleaf pines started on an exploratory basis on the Olustee Experimental Forest in 1936. As there was no particular need for increased supplies of naval stores at that time, the work was conducted on a very limited basis. However, with the events which led to World War II and the accompanying increased demand for naval stores, this work was given strong impetus and the original studies were intensified and expanded. Considerable experimental data are now available on chemical stimulation, including the results which can be expected under field conditions. A description of these studies and the conclusions drawn from them are presented in this paper, which summarizes progress to date with particular emphasis on the work of 1942 and 1943.

HISTORICAL BACKGROUND

Following World War I, Germany and Russia initiated intensive programs to improve and expand their naval stores industries. It was during this initial period of expansion, when these countries were attempting to devise means of becoming self-sufficient in all important raw materials, that the use of chemicals to stimulate gum yields first received attention.

The Germans (12, 13, 17, 23) initiated studies in the use of chemicals to stimulate gum flow in 1933, and somewhat similar work was started in Russia (1, 30, 31, 32, 34) at about the same time. In these early exploratory experiments many different types of chemicals were used as liquids, solids, or gases, and included acids (organic and inorganic), bases, pure salts, various solvents, oxidizing and reducing agents, poisons, and relatively inert substances like alcohol, sugars, ether, and oils.

Many of the substances tested exhibited a stimulating action on the flow of gum. A few, such as sulphuric and hydrochloric acids, and sodium and potassion hydroxides, were outstanding. Much of the subsequent work has been with these chemicals. The small attention given the other chemicals does not preclude their potential value in stimulation, but indicates simply that in the concentrations tested, and under the experimental conditions prevailing, they did not cause as much increase in gum flow as the two acids and bases mentioned.

Many different techniques, as well as chemicals, were tried in the early European work. These included methods of applying chemicals, variations in chipping heights and depths, and different frequencies of treatment and chipping.

In this country the first work on chemical stimulation was started in 1936 as a cooperative study by the Southern Forest Experiment Station, U. S. Forest Service, at the Olustee Experimental Forest, Lake City, Fla., and the Bureau of Agricultural and Industrial Chemistry (formerly Bureau of Chemistry and Soils). Results of this early exploratory study were inconclusive. At that time there was a surplus of turpentine and rosin, prices were low, and there was little interest in chemical stimulation, but in 1938 a larger experiment was started to explore the possibilities further (18).

The promising increases in yield obtained in the 1938 experiment, even at the low concentrations in which the stimulants were used, gave further impetus to research and additional work on yield capacities of individual trees was done in 1940. These yield records served as the basis for dividing the trees into yield-capacity groups which were almost identical. Then in the 1941 season one group of trees was worked untreated, and the others assigned treatments which covered a wide concentration range of sulphuric and hydrochloric acids, the two chemicals giving best results in the former experiments. The results of this study (19, 20) formed an important link in the chain of evidence upon which recommendations to industry were made in 1942 (20) and 1943 (22).

Shortly after our entry into World War II an intensified research program on the use of chemical stimulants was instituted. This covered the use of many different chemicals in varying concentrations, numerous variations in chipping and treatment schedules, variations in height, depth, and frequency of chipping, studies on species differences, and the effect of chemicals on gum quality and the health and vigor of the trees. The results of this latest work are summarized in this paper and provide a basis for the latest recommendations to the industry (25). Further intensive tests are underway and additional data will be reported as available.

EXPERIMENTAL TECHNIQUES

In testing the influence of any treatment on yields from naval stores streaks, it has been found necessary to determine the natural yielding capacity of all trees and to arrange the trees into treatment groups of approximately the same capacity. The natural yielding capacity of trees varies not only with bole size and crown development but also with site and possible inherent qualities (27). The most effective manner of determining the yielding capacity of a tree was found to be through a calibration period of several weeks in which the tree is subjected to standard chipping practice and the yields carefully weighed. In these experiments it was found that the yielding capacity of a tree usually could be determined from 4 standard 1/2-inch streaks applied weekly. Both extremely high and extremely low producing trees were excluded from the treatment groups used in the studies.

Assignment of trees to treatment groups was done at random within each yield class, resulting in a moderately uniform distribution of trees of yielding capacities varying from the low to the high. The general yielding level of each group, before treatments started, was then essentially similar, so that differences observed in yield between groups could be attributed primarily to treatment. Enough replications were used for each treatment so that statistically significant yield differences greater than about 15 to 30 percent could be detected, the precision depending on the purpose of the specific experiment.

Species differences in response to chemical treatment were noted in early work, so most experiments were set up for both slash and longleaf pines in order to find the optimum treatment applicable to each. Second-growth stands of slash and longleaf of varying ages and diameters and chiefly of a single species were used in the tests, representing the range of timber types in the vicinity of Olustee, Fla.

Gum yields were obtained for each tree at regular intervals throughout the season, either weekly or biweekly; in one instance gum yields after 1 and 3 days were also obtained. This method provided data on the trend of yield response for individual trees as well as treatments. Valuable information on effective treatment periods was also obtained by this procedure.

Miscellaneous details of experimental technique include face widths one-third of the circumference on trees over 9 inches d.b.h., although standard uniform widths were used on all trees in certain experiments. Galvanized gutters and aprons were inserted with a broadax. Streaks were chipped 1/2-inch deep and 1/2-inch high, using a No. 0 hack unless otherwise specified. In the early work the chemical solution was applied with a brush, or glass cloth swab. Later a nasal-type spray atomizer was used. In more recent experiments chemicals were applied with a special spraygun equipped with a hand pump. All experiments were so designed as to allow for statistical examination of the data.

INVESTIGATIONAL WORK AND RESULTS

The general objectives of this research on chemical stimulants were to determine the best chemical treatments to increase the production of gum naval stores, and to develop methods for the use of chemicals adapted to conditions in the industry.

To accomplish these objectives numerous experiments were undertaken during the 1942 and 1943 seasons, covering many phases of chemical stimulation. Since some experiments were quite comprehensive, cross references will be made frequently under the separate headings in the following discussions.

The results from some of these studies are tentative in character, as only preliminary tests were made. In other instances the results are quite indicative of what may be finally expected, because supporting evidence is either available in replications in the station's work, or substantiated by workers in other countries. The qualifications applicable to each phase of study are pointed out in detail in the discussion so as to avoid erroneous conclusions.

Effectiveness of Different Chemicals

Many chemicals, some of which were tested at numerous concentrations, have been used during the last 10 years in attempts to increase gum yields by the use of chemical stimulants. The results have varied from an increase of about 250 percent to a decrease of almost 40 percent. Some chemicals have proven to be very consistent in their effect; others were variable. In general, strong acids and strong bases have been the classes of chemicals giving the best results, although some inorganic salts have indicated promise. Tables 1, 2, and 3 summarize the general results obtained with a variety of chemicals in Europe and at the Southern Forest Experiment Station.

The results of Kublun and others (table 1) show that a great many chemicals exert a stimulating effect on gum production in Scotch pine, Pinus sylvestris, varying markedly in intensify of effect for the different chemicals. The reported amount of stimulation is very high when compared to our results with slash and longleaf pines, but several factors are involved. Fundamental species differences in response to applied chemicals probably exist. Scotch pine is an extremely poor gum producer when judged by our slash or longleaf pine standards, or even by those for the maritime pine in France or the Aleppo pine in Spain and Portugal. Small increases loom larger, with a relatively small total amount involved, when expressed on a percentage basis. Thus an increase of 200 percent on a 50-barrel crop would amount to a total yield of 150 barrels, while on a 100-barrel crop (rather low by our standards) an increase of only 50 percent would result in the same total yield.

The fact that Scotch pine shows a positive response to many chemicals would appear to indicate a more sensitive species capable of response to a relatively weak stimulation. On the other hand slash and longleaf might be capable of a stronger "buffering" capacity in resisting change by added chemicals. The fundamental mechanism of response to applied chemicals may also contribute to this differential reaction.

All acids used caused some gum-flow stimulation at certain concentrations, but only two were consistently outstanding in promoting large increases in gum production, namely, sulphuric and hydrochloric acids. After initital experiments here and abroad, most subsequent work concerned these two chemicals, which were used in a number of concentrations with variations in chipping techniques and treatment schedules. Other inorganic acids such as nitric and phosphoric were relatively ineffective at the lower concentrations but caused a considerable increase in gum flow at extremely high concentrations. It is difficult to reconcile the fact that sulphuric but not nitric acid brings about large increases in the flow of gum, although both are strong acids in a chemical sense. A number of inorganic acids had little effect on gum yields; these include boric, chromic, and perchloric acids. Organic acids, such as acetic, formic, lactic, picric, pyrogallic, and tannic acids, were relatively ineffectual. Certain growth substances such as indoleacetic, indolebutyric, and naphthaleneacetic acids in the strengths and combinations used gave little promise of stimulating gum yields markedly.

Early work also showed that strong bases, such as sodium and potassium hydroxides, resulted in greatly augmented gum yields, while ammonium hydroxide, a weak base, was only effective at a very high concentration. This held true for Scotch, slash, and longleaf pines.

Both strong acids and strong bases at relatively high concentrations were thus found to be effective stimulants of gum yields. That both classes of chemicals should work almost precludes certain theories of "acidity" in explaining the basic action involved in chemical stimulation, although changes in acidity of tissue immediately above the face probably plays an important role.

Many salts were used, ranging from common table salt, sodium chloride, to corrosive or poisonous chemicals like potassium bichromate, ammonium thiocyanate, and arsenic pentoxide, but relatively small yield responses were obtained. Other relatively inert substances like alcohol, glycerine, and sugar were in this same category. At other concentrations, and other means of application, some of these may prove more effective, and work is being continued on a moderate scale on their use.

Table 1.—Results of several foreign investigations on the use of chemicals to stimulate gum yields in Scotch pine, *Pinus sylvestris*

Investigator and chemicals tested	Percent concentration	Percent increase in yield Streak 1	Streak 2
KUBLUN (17)			
Acetic acid	10	29	10
Acetic acid	50	36	*
Acetic acid	conc.	46	*
Formic acid	10	52	23
Formic acid	50	62	*
Formic acid	conc.	60	*
Lactic acid	50	57	21
Lactic acid	90	49	37
Ethyl-sulphuric acid	25	74	76
Ethyl-sulphuric acid	50	92	89
Sulphuric acid	10	15	14
Sulphuric acid	25	30	82
Sulphuric acid	50	123	118
Hydrochloric acid	10	17	32
Hydrochloric acid	25	118	107
Hydrochloric acid	33	109	100
Lactic acid	25	33	15
Phosphoric acid	20	*	26
Boric acid	3	79	68
Potassium hydroxide	10	13	45
Potassium hydroxide	20	57	100
Sodium chloride	10	*	22
Potassium chloride	10	*	37
Potassium chloride	40	20	32
Potassium carbonate	40	32	40
Hydrogen peroxide	3	8	22
Phenol	5	*	11
		Season	
Nitric acid	10	61	
Nitric acid	25	32	
Nitric acid	50	75	
Alcoholic acetic acid	25	23	
Alcoholic acetic acid	50	29	
Alcoholic formic acid	25	39	

*Indicates no difference or decrease

Chromic acid	20	44
Tannic acid	20	25
Boric acid	3 parts	59
Sulphuric acid	10 parts	
Alcohol	10 parts	
Boric acid	3 parts	6
Sulphuric acid	10 parts	
Alcohol	10 parts	
Water	10 parts	
Sulphuric acid	5 parts	59
Potassium bichromate	1 part	
Water	4 parts	
Alcoholic potassium hydroxide	10	16
Ammonia hydroxide	10	7
Ammonia hydroxide	20	50
Sugar	5	41
Alum	10	12
Sodium acetate	20	43
Sodium formate	20	38
Alcohol	50	*
Alcohol	95	*
Glycerine	conc.	21
NIKOLAEV & SINELOBOV (31)		
Chlorine gas	--	increases
Sulphuric gas	--	increases
NIKOLAEV & SINELOBOV (32)		
Sulphuric acid	60	144 (average)
Sulphuric acid	conc.	250 (approx.)
Hydrochloric acid	conc.	103 (average)
HESSENLAND (12)		
Sulphuric acid	50	128
Alcoholic sulphuric acid	50	104
Hydrochloric acid	10	32
Hydrochloric acid	25	115
Formic acid	6	67
Potassium hydroxide	10	45
Potassium hydroxide	20	111
Ammonia hydroxide	10	7
Ammonia hydroxide	20	50
Sodium chloride	10	22
Calcium chloride	40	37

*Indicates no difference or decrease

Table 2.- Gum yields of longleaf pine treated with various chemicals during portions of the 1942 season using 1/2-x 1/2-inch chipping at the Olustee Experimental Forest

Chemical treatment	Percent concentration	Percent increase (+) or decrease (-)
Acetic acid	5	-19
Acetic acid	20	-28
Ammonium hydroxide	5.6	-13
Ammonium hydroxide	14	+ 4
Ammonium hydroxide	28	+39
Ammonium sulphamate	2.5	+18
Ammonium sulphamate	5	- 5
Ammonium sulphamate	10	+20
Ammonium sulphamate	25	- 6
Ammonium sulphamate	40	-27
Ammonium thiocyanate	2	-24
Ammonium thiocyanate	5	-25
Ammonium thicyanate	10	-17
Arsenic pentoxide	18.8	+ 7
Arsenic pentoxide	37.5	+27
Arsenic pentoxide	75	± 0
Arsenic trioxide	0.15	-18
Arsenic trioxide	0.3	- 8
Arsenic trioxide	0.6	-12
Borax-boric acid	10	- 9
Borax-boric acid	20	- 9
Borax-boric acid	30	+10
Ethylene chlorhydrin	5	- 3
Ethylene chlorhydrin	10	- 1
Ethylene chlorhydrin	20	- 2
Formaldehyde	10	- 4
Formaldehyde	25	+ 4
Formaldehyde	40	-34
Growth substances:		
Indolebutyric acid	50 ppm	- 9
Indoleacetic acid	25 ppm	
Naphthaleneacetic acid	25 ppm	
Mercuric chloride	1	-12
Mercuric chloride	2	-16
Nitric acid	20	-16
Nitric acid	33	-18
Nitric acid	50	+10
Perchloric acid	5	-14

Table 2. - continued

Perchloric acid	10	±0
Perchloric acid	20	+10
Phenol	1.4	- 7
Phenol	2.3	-16
Phenol	7	- 9
Phosphoric acid	30	- 4
Phosphoric acid	45	+ 8
Phosphoric acid	90	+29
Picric acid	0.17	+10
Picric acid	0.35	-12
Picric acid	1.4	- 6
Potassium hydroxide	5	- 3
Potassium hydroxide	10	- 4
Potassium hydroxide	20	+17
Potassium hydroxide	40	+38
Pyrogallic acid	5	-36
Silver nitrate	2.5	- 9
Silver nitrate	5	-13
Sodium chlorate	2	- 7
Sodium chlorate	5	- 3
Sodium chlorate	10	+12
*Sulphuric acid + arsenic pentoxide	1 and 1	+20
Sulphuric acid + arsenic pentoxide	1 and 2	+16
Sulphuric acid + arsenic pentoxide	5 and 1	- 4
Sulphuric acid + arsenic pentoxide	5 and 2	- 4
Sulphuric acid + arsenic pentoxide	10 and 1	+ 8
Sulphuric acid + arsenic pentoxide	10 and 2	+10
Sulphuric acid + arsenic trioxide	40 and 0.20	+55

*For more complete information on results with sulphuric acid see table 3; and for chemical combinations see table 4.

Table 3. - Gum yields of slash and longleaf pines receiving chemical treatments with the most promising stimulants at the Olustee Experimenal Forest*

Chemical treatment	Percent concentration	Percent increase (+) or decrease (-) Slash	Longleaf
	Weekly chipping and treatment		
Hydrochloric acid	8	+34	-30
Hydrochloric acid	16	+50	- 2
Hydrochloric acid	24	+45	+ 7
Hydrochloric acid	28	--	+ 9
Hydrochloric acid	32	--	+21
Hydrochloric acid	35	--	+ 1
Sulphuric acid	5	-18	-14
Sulphuric acid	20	+28	-12
Sulphuric acid	30	+29	-12
Sulphuric acid	40	+63	+35
Sulphuric acid	60	+68	+60
Sulphuric acid	75	--	+44
Sulphuric acid	90	--	+54
Sodium hydroxide	5	+ 8	+16
Sodium hydroxide	15	+41	+25
Sodium hydroxide	25	+37	+38
Sodium hydroxide	50	--	+66
	Biweekly** chipping and treatment		
Sulphuric acid	40	+22	- 8
Sulphuric acid	60	+20	+ 9
Sodium hydroxide	5	-26	-40
Sodium hydroxide	25	-19	-25
	Triweekly** chipping and treatment		
Sulphuric acid	40	- 9	-56
Sulphuric acid	60	-26	-28
	"Skip" - weekly chipping and biweekly treatment		
Sulphuric acid	40	+45	+32
Sulphuric acid	60	+41	+44
Sodium hydroxide	5	+19	- 9
Sodium hydroxide	25	+25	+ 7

*Percent increase or decrease based on untreated controls chipped 1/2- x 1/2-inch weekly.
**Biweekly and triweekly refers to chipping and/or treatment at two- or three-week intervals.

Table 4. - Gum yields of slash and longleaf pines chipped weekly and treated with various chemical combinations

Species, type of chipping, and chemical treatment*	No. of streaks	Av. yield in grams	Percent increase
Longleaf I (Regular 1/2- x 1/2-inch chipping)			
Untreated	10	925	--
40% Sulphuric acid, H_2SO_4	10	1053	13.9
40% H_2SO_4 + 0.958% Cupric sulphate	10	1029	11.2
40% H_2SO_4 + 1.821% Potassium aluminum sulphate	10	1346	45.5
40% H_2SO_4 + 0.619% Zinc sulphate	10	1206	30.3
Longleaf II (Regular 1/2- x 1/2-inch chipping)			
Untreated	21	1969	--
40% Sulphuric acid, H_2SO_4	21	2501	27.0
40% H_2SO_4 + 0.998% Sodium arsenite	21	3049	54.9
Slash I (Regular 1/2- x 1/2-inch chipping)			
Untreated	15	1562	--
40% Sulphuric acid, H_2SO_4	15	2404	53.9
40% H_2SO_4 + 0.998% Sodium arsenite	15	2890	84.9
25% Sodium hydroxide, NaOH	15	2233	42.9
25% NaOH + 0.998% Sodium arsenite	15	2271	45.4
Slash II (Bark chipping 1/2 inch high)			
Untreated	9	815	--
40% Sulphuric acid, H_2SO_4	9	1391	70.6
40% H_2SO_4 + 0.523% Potassium phosphate	9	1614	97.9

*Twentieth molar concentrations of added chemicals were used in this preliminary work, thus the expression of concentration in percent results in decimal figures.

Effectiveness of Chemical Combinations

Certain chemical combinations, involving the use of two or more chemicals in the same solution, give promise of being even better than the single chemical solutions tested to date (table 4). This effect has been synergic in more than one instance, the stimulation results being more than additive for the chemicals used, and is typified by the yields obtained with acid plus arsenic (38) as indicated in table 2.

Three of the four chemical combinations tried on longleaf pine appear to have promise as effective yield stimulants. With slash pine two of the three chemical combinations used resulted in yield increases greater than those obtained with sulphuric acid alone. All were considerably above the level of increase obtained with 40-percent sulphuric acid. This is particularly noteworthy since concurrent work showed that in general 40-percent is not nearly as effective as 60-percent sulphuric acid on longleaf. The increased yields obtained with these chemical combinations approached the best resulting from 60-percent sulphuric acid treatment.

The acid-arsenic solution gave good results on both pine species with regular chipping 1/2 inch deep and 1/2 inch high. Phosphorous added to sulphuric acid also gave a greatly augmented yield response on slash pine with bark chipping 1/2 inch in height. Added zinc sulphate increased yields somewhat on longleaf, while potassium aluminum sulphate resulted in even greater yield increases almost equal to those with acid-arsenic. The latter appeared best on longleaf, among the chemicals tried, as far as increased yields were concerned. The value of added arsenic in chemical stimulation techniques is enhanced by its influence in inhibiting iron corrosion (38).

An acid-arsenic solution was first chosen because of its being an inhibitor of iron corrosion (4). The success of this combination in a subsequent preliminary test of its effect on yields led to trials of the other combinations listed. The choice of the specific chemicals used was based on their relative closeness in the group of elements called heavy metals, and their chemical behavior, particularly as catalysts in certain reactions. Others in the same group, such as antimony, bismuth, and selenium were not used for reasons of availability, cost, and possibly lower reaction rates.

These results, although indicating great promise for chemical combinations, are preliminary in character. They are based on only one season of work and are far short of encompassing the enormous range of possible combinations of chemicals and concentrations that may be tested. Further work on a moderate scale is under way.

Table 5. - Yield results for three years of chemical stimulation with weekly 1/2- x 1/2-inch chipping on slash pine

Chemical treatment	Av. yield: in grams 1940**	Percent increase in yield* 1941	1942	1943
Untreated***	3585	3790	3676	3606
20% Sulphuric acid	3585	28	22	20
30% Sulphuric acid	3585	29	9	11
40% Sulphuric acid	3585	47	17	18
8% Hydrochloric acid	3585	34	13	14
16% Hydrochloric acid	3585	50	26	23
24% Hydrochloric acid	3585	45	14	10
Washing soda	3585	9	6	--

*Seasons: 1940 - April 2 to November 5, 32 streaks; 1941 - April 1 to November 4, 32 streaks; 1942 - April 8 to December 9, 35 streaks; 1943 - April 5 to November 15, 32 streaks.
**Chipped weekly all season without chemical treatment for purposes of calibration.
***Average yield in grams of untreated control for each year of working.

Table 6. - Yield results for study of variations in frequency of chipping with different chemical treatments on slash pine

Chemical treatment	Frequency of chipping	1942 (16 streaks) Average yield in grams*	Percent increase or decrease	1943 (32 streaks) Average yield in grams*	Percent increase or decrease
Untreated	Weekly	2094	--	4459	--
5% NaOH	Weekly	2267	+ 8	--	--
15% NaOH	Weekly	2952	+41	4949	+11
25% NaOH	Weekly	2866	+37	5256	+18
60% H_2SO_4	Weekly	3526	+68	6379	+43
5% NaOH	Biweekly	1554	-26	--	--
25% NaOH	Biweekly	1698	-19	3132	-30
40% H_2SO_4	Biweekly	--	--	4567	+ 2
60% H_2SO_4	Biweekly	2117	+ 1	4318	- 3
5% NaOH	Skip	2484	+19	--	--
25% NaOH	Skip	2620	+25	5314	+19
40% H_2SO_4	Skip	3032	+45	6388	+43
60% H_2SO_4	Skip	2945	+41	5921	+33
40% H_2SO_4	Triweekly	--	--	4047	- 9
60% H_2SO_4	Triweekly	--	--	3296	-26

*Average yield in grams for season (1942 - August 13 to November 26; 1943 - April 6 to November 16); all percents are calculated on basis of 1/2 x 1/2 inch untreated weekly chipping.

Table 7. - Yield results for study of variations in frequency of chipping with different chemical treatments on longleaf pine

Chemical treatment	Frequency of chipping	1942 (16 streaks) Average yield in grams*	Percent increase or decrease	1943 (32 streaks) Average yield in grams*	Percent increase or decrease
Untreated	Weekly	1406	--	2675	--
5% NaOH	Weekly	1634	+16	--	--
15% NaOH	Weekly	1761	+25	3035	+13
25% NaOH	Weekly	1942	+38	3257	+22
40% H_2SO_4	Weekly	--	--	3617	+35
60% H_2SO_4	Weekly	2061	+47	2962	+11
5% NaOH	Biweekly	850	-40	--	--
25% NaOH	Biweekly	1057	-25	1873	-30
40% H_2SO_4	Biweekly	1298	- 8	1885	-30
60% H_2SO_4	Biweekly	1531	+ 9	2274	-15
5% NaOH	Skip	1276	- 9	--	--
25% NaOH	Skip	1509	+ 7	2829	+ 6
40% H_2SO_4	Skip	1856	+32	3011	+13
60% H_2SO_4	Skip	2022	+44	2990	+12
40% H_2SO_4	Triweekly	--	--	1185	-56
60% H_2SO_4	Triweekly	--	--	1914	-28

*Average yield in grams for season (1942 - August 21 to December 4; 1943 - April 6 to November 17): All percents are calculated on basis of 1/2- x 1/2 inch untreated weekly chipping.

Importance of Chemical Concentration

Increased concentrations of effective chemicals result in maximum increases in gum yields, but this higher level of gum yield is not maintained over a very long period. For instance, when extremely high concentrations of sulphuric acid are used, such as 75, 90, or 96 percent (concentrated), immediate gum yields are generally very much greater for several streaks. This high yield level usually decreases shortly to that for lower concentrations, possibly because of temporary damage to the living tissue for some distance above the face, or because of a relatively sudden depletion of oleoresin below the level of synthesis supply. It has also been found that a moderate concentration, such as 60 percent on slash pine, brings about good results the first season but appears to be less effective during successive years. This is illustrated in tables 5 to 7, inclusive. Important factors concerned with these lowered yield increases in succeeding years are discussed later under "Effective Treatment Period."

Increasing the amount of chemical applied influences yields in a manner similar to that of increasing concentration. Results with heavy application at weaker concentrations are relatively comparable to light application at higher concentrations. This probably holds true when we consider the total amount applied to the streak, as well as the completeness of coverage obtained. These factors are covered adequately in a recent publication by Dorman, True, and Clements (6). This was also emphasized in another experiment (table 8) where considerable care was taken to obtain adequate and complete coverage of the face in applying acid. Increases of over 100 percent in gum yield resulted from this careful treatment; this is considerably more than resulted from only average care in treatment as indicated in tables 5 to 7, inclusive.

Table 8. - Yield increases in slash pine obtained with careful treatment

Type of cupping	Type of chipping	Chemical treatment	Av. weekly yield in	Percent of untreated
Virgin face	Regular 1/2 x 1/2 inch	Untreated	105	100
Virgin face	Regular 1/2 x 1/2 inch	40% H_2SO_4	232	221
Back face	Regular 1/2 x 1/2 inch	Untreated	98	100
Back face	Regular 1/2 x 1/2 inch	40% H_2SO_4	168	171
Back face	Bark chip. 1/2 inch ht.	40% H_2SO_4	214	218

Choice of the optimum concentration for any one species treated on a given schedule must depend on the integration of all factors concerned. These include frequency of application, the effect on yields during successive years of treatment, and thoroughness of application. All of these were considered before making the recommendations reported by Mitchell (25). He states that ". . . a 40 percent solution of sulphuric acid is most effective on slash pine, whereas a 60 percent solution works best on longleaf pine. Thus, for best results, use a 40 percent solution on pure or predominately slash pine timber, and a 60 percent solution on pure or predominately longleaf pine timber. If the two species are equally represented, or nearly so, use the 60 percent solution."

Frequency of Chemical Treatment and Chipping

The action of applied chemical stimulants appears to be expressed more in prolongation of gum flow than in initial acceleration. Figure 1 indicates the general type of response for a typical weekly interval, and figures 2 to 5 show ~~that~~ the yield results for longer periods.

The average amount of gum exuded during the first 48 hours following chipping (fig. 1) is essentially the same for treated and untreated trees. The basic data for figure 1 were obtained with continuous-recording gum-flow meters (21), thus making it possible to determine that both the treated and untreated streaks show the typical diurnal rise and fall in rate of flow, running more during the day and decreasing at night. After about the first two days the average daily yield of gum from untreated trees gradually diminishes from day to day (11, 21). The flow of gum from treated trees, on the other hand, continues at approximately the same rate for a much longer time and only after weeks, instead of days, does the daily gum output decline to negligible amounts (fig. 5).

It is evident, from the trends exhibited by different frequencies of chipping and chemical treatment, that a proportionately greater amount of gum can be obtained from chemically treated streaks, than from untreated streaks chipped at intervals greater than one week. Figure 2 shows that essentially the same amount of gum can be obtained in 2 weeks from a single acid-treated streak as from two untreated streaks put on at weekly intervals, and (in this case) almost 80 percent more gum than from a single untreated streak during the same interval. On a triweekly basis of chipping and treatment (fig. 3) almost as much gum can be obtained as if the trees were chipped at weekly intervals. When chipped every 4 weeks, as illustrated in a typical experiment shown in figure 4, the yield from treatment is about double that obtained without applied chemicals. Diminishing returns follow at longer chipping intervals, since after 8 weeks (fig. 5) there was an increase of only 120 percent as a result of treatment. This latter is of theoretical interest only, however, as such long chipping intervals are not economically practical, and would not be recommended for general use.

Thus, there is a definite interval of chipping and treatment that will result in maximum yields consistent with the amount of labor expended. The only full season's results available now for different intervals are for weekly, biweekly, and triweekly chipping and treatment (tables 6 to 9, inclusive). The biweekly results (tables 6 and 7) for a whole season's treatment with acid substantiate the trend shown in figure 2, i. e., just as much gum during 14 days from a single acid-treated streak as from two

weekly untreated streaks. Although no adequate basis for a comparison of the triweekly results is available in the chemical stimulation data, ample yield records are available from previous experiments. These provide a good basis for estimating ratios of treatment yields to untreated streaks at various intervals of chipping.

These are the basic data for Mitchell's 1944 recommendation (25) for periodic acid treatment: ". . . applying sulphuric acid, immediately after chipping, to all streaks chipped during the spring and summer months." As he points out, maximum total production for a season may be obtained by chipping and treating the entire croppage on the average of once each week, but under conditions of labor shortages more gum may be obtained by applying acid each time a tree is chipped, regardless of the frequency of chipping.

An interesting variation in chipping and treatment schedules, where considerable yield increases over regular weekly untreated chipping were obtained, is the "skip treatment," in which a tree is chipped each week, with acid being applied every other week, (tables 6 and 7). This treatment is the only one showing consistently high yield increases the second season, with the extra gum yields approaching, but not quite equaling, weekly chipping with acid treatment.

This discussion so far has dealt with acid treatment. A strong base, such as sodium hydroxide, does not prolong the flow of gum for much longer than one week. No daily gum-flow measurements were made with base treatment, but repeated weekly weighings with biweekly chipping and treatment with sodium hydroxide indicated that over 80 percent of the increased yield came in the first week. It has also been noted that a number of treated streaks (using sodium hydroxide) must be put on before yield increases are built up to a maximum. These facts restrict the use of sodium hydroxide to a regular weekly chipping and treatment schedule in order to obtain maximum yields for the labor expended.

FIGURE NO. 1

ACCUMULATIVE HOURLY GUM YIELDS OF SLASH PINE WITH AND WITHOUT TREATMENT WITH 40% H_2SO_4

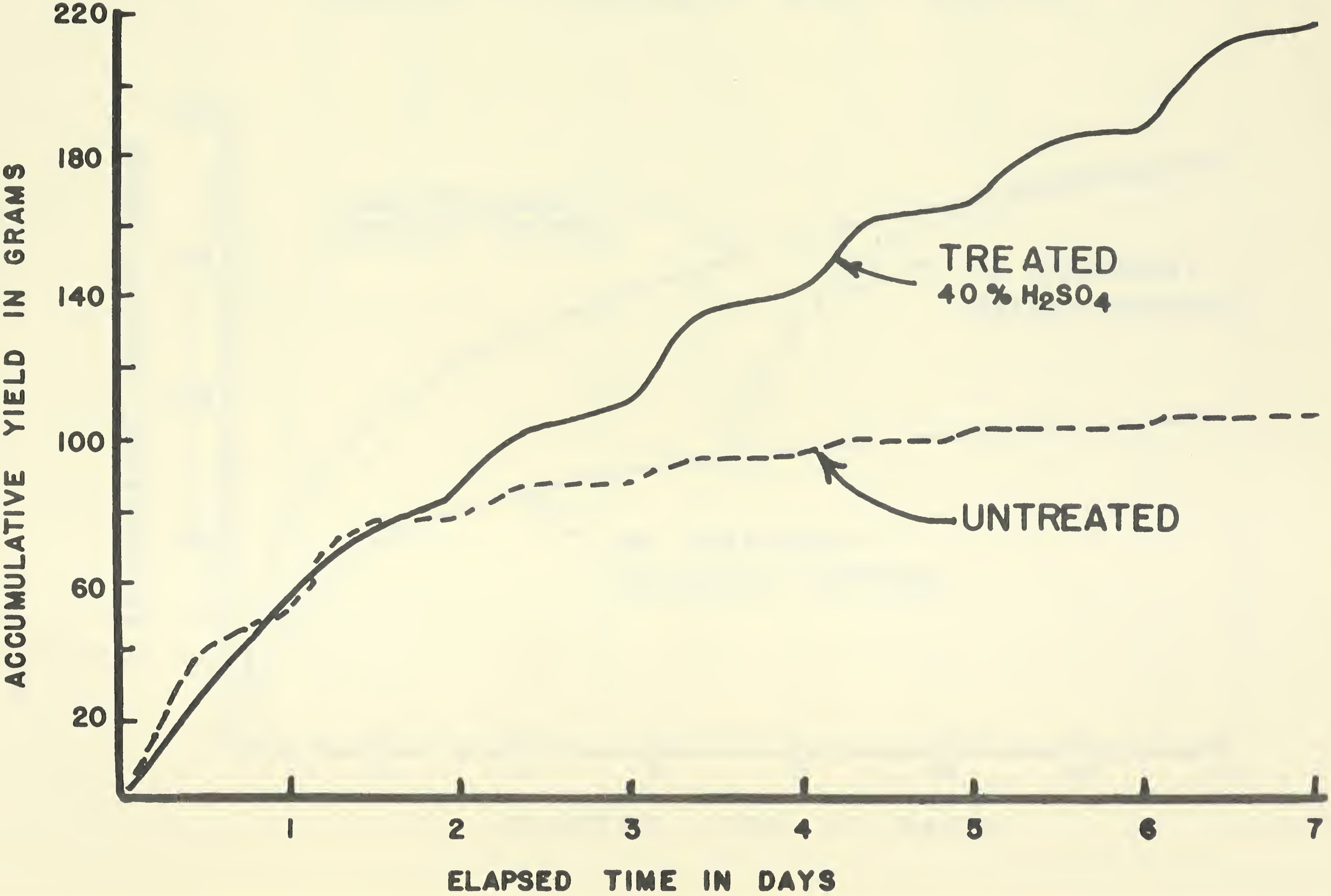


FIGURE NO. 2

ACCUMULATIVE DAILY GUM YIELDS OF ONE TREATED AND TWO UNTREATED STREAKS FOR A TWO WEEK PERIOD — LONGLEAF PINE — 24% HCL

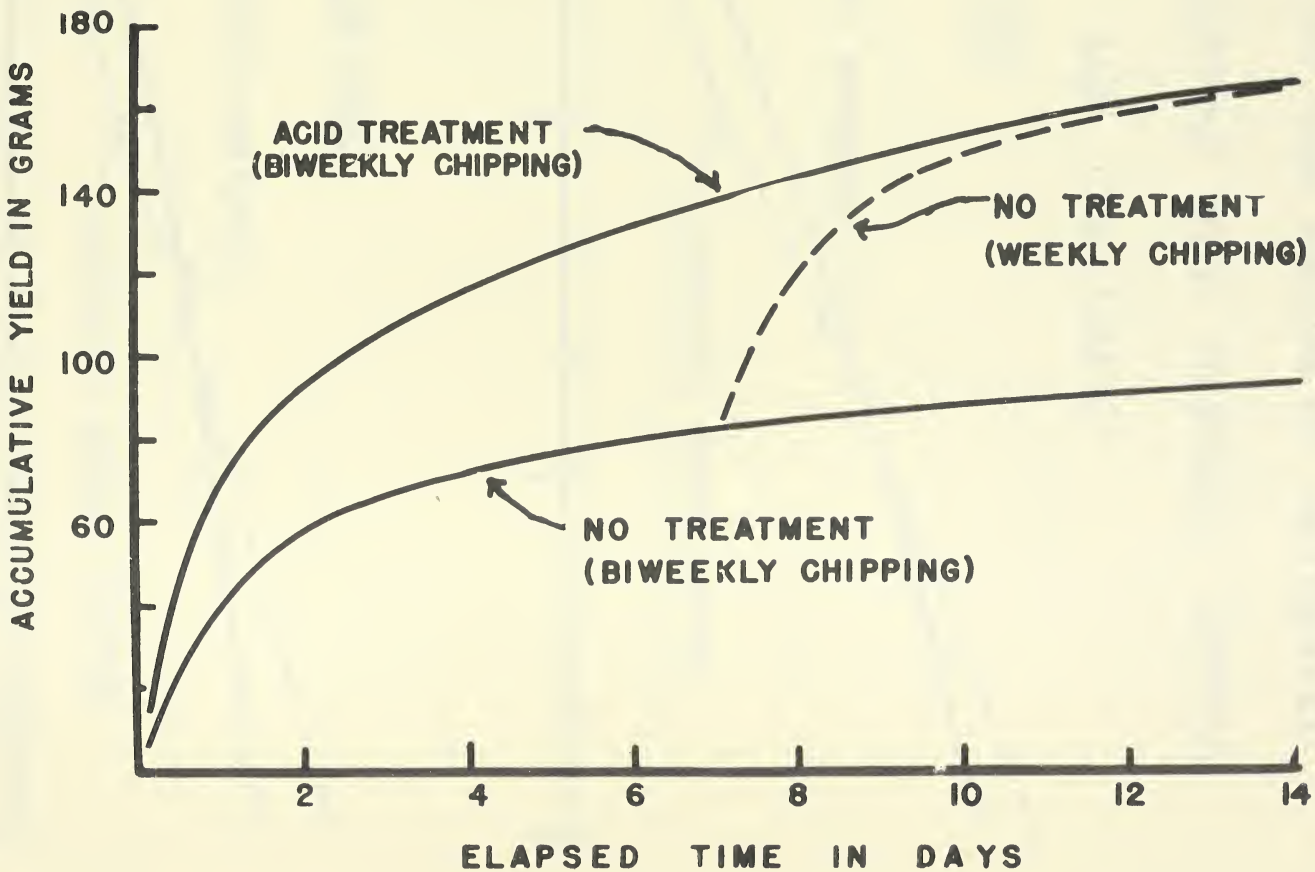


FIGURE NO. 3

COMPARATIVE GUM YIELDS OF UNTREATED WEEKLY CHIPPING WITH TRIWEEKLY CHIPPING AND TREATMENT

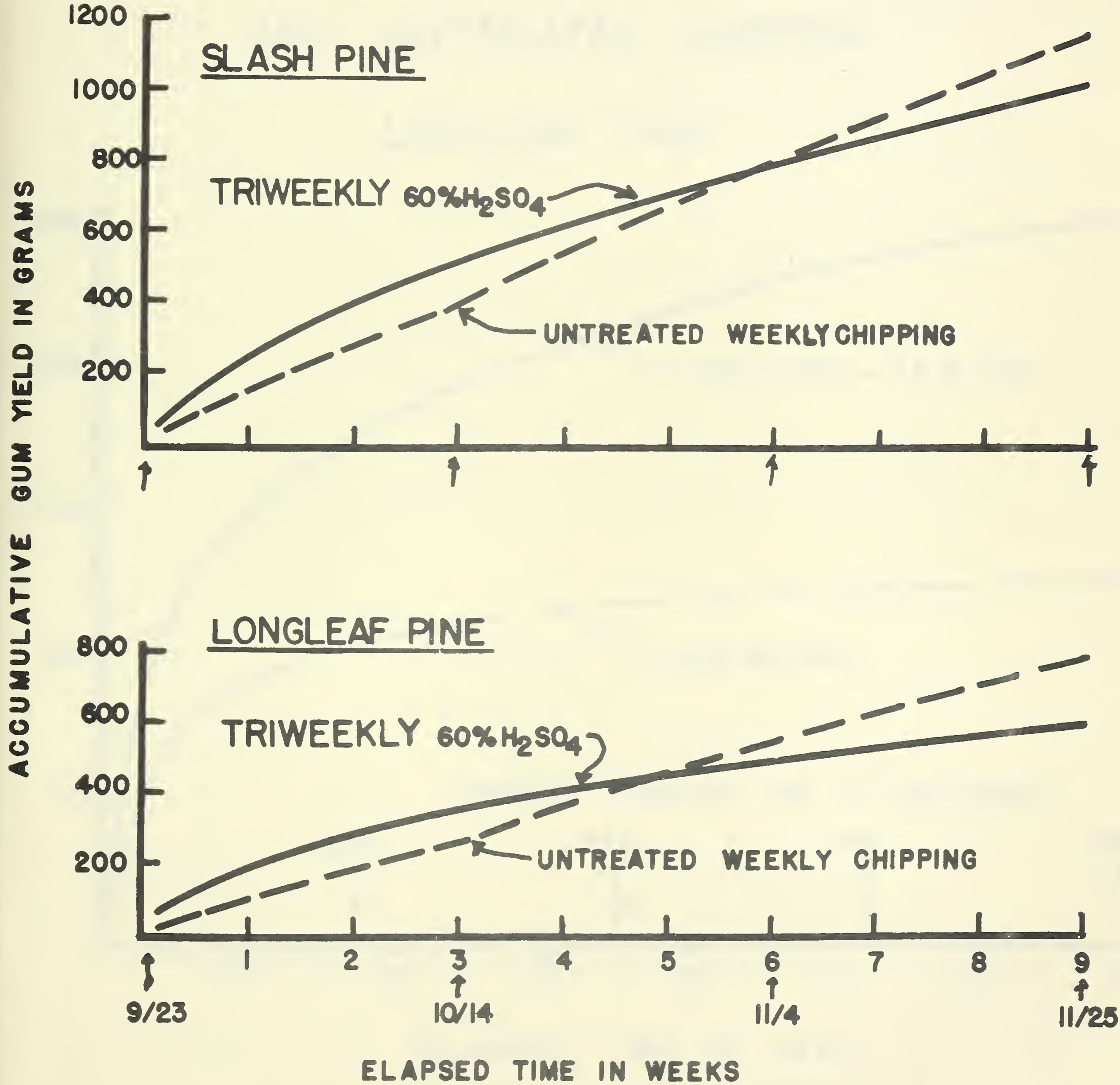


FIGURE NO. 4

ACCUMULATIVE DAILY GUM YIELDS FOR A PERIOD OF 4 WEEKS FOLLOWING TREATED AND UNTREATED CHIPPING LONGLEAF PINE

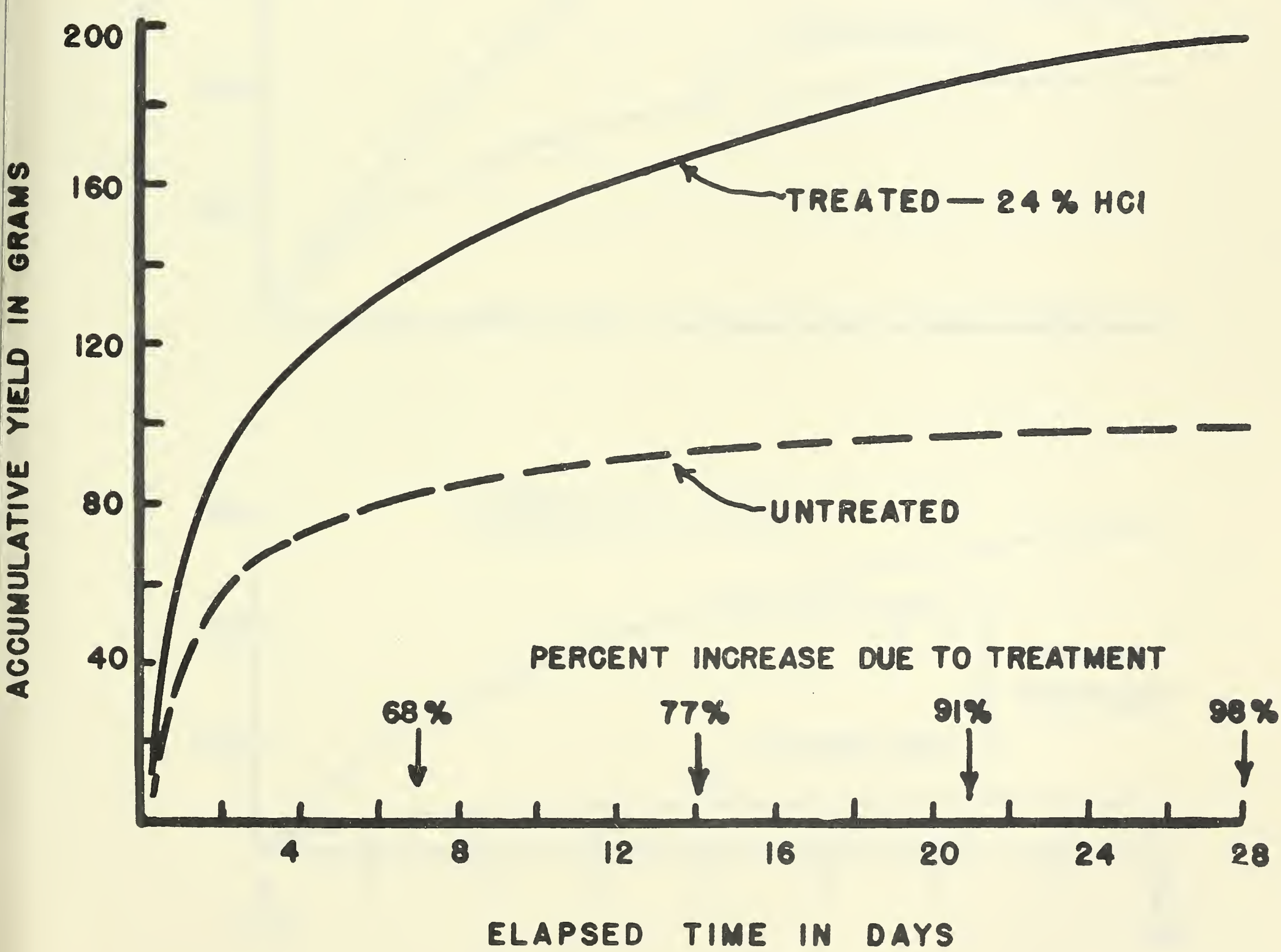
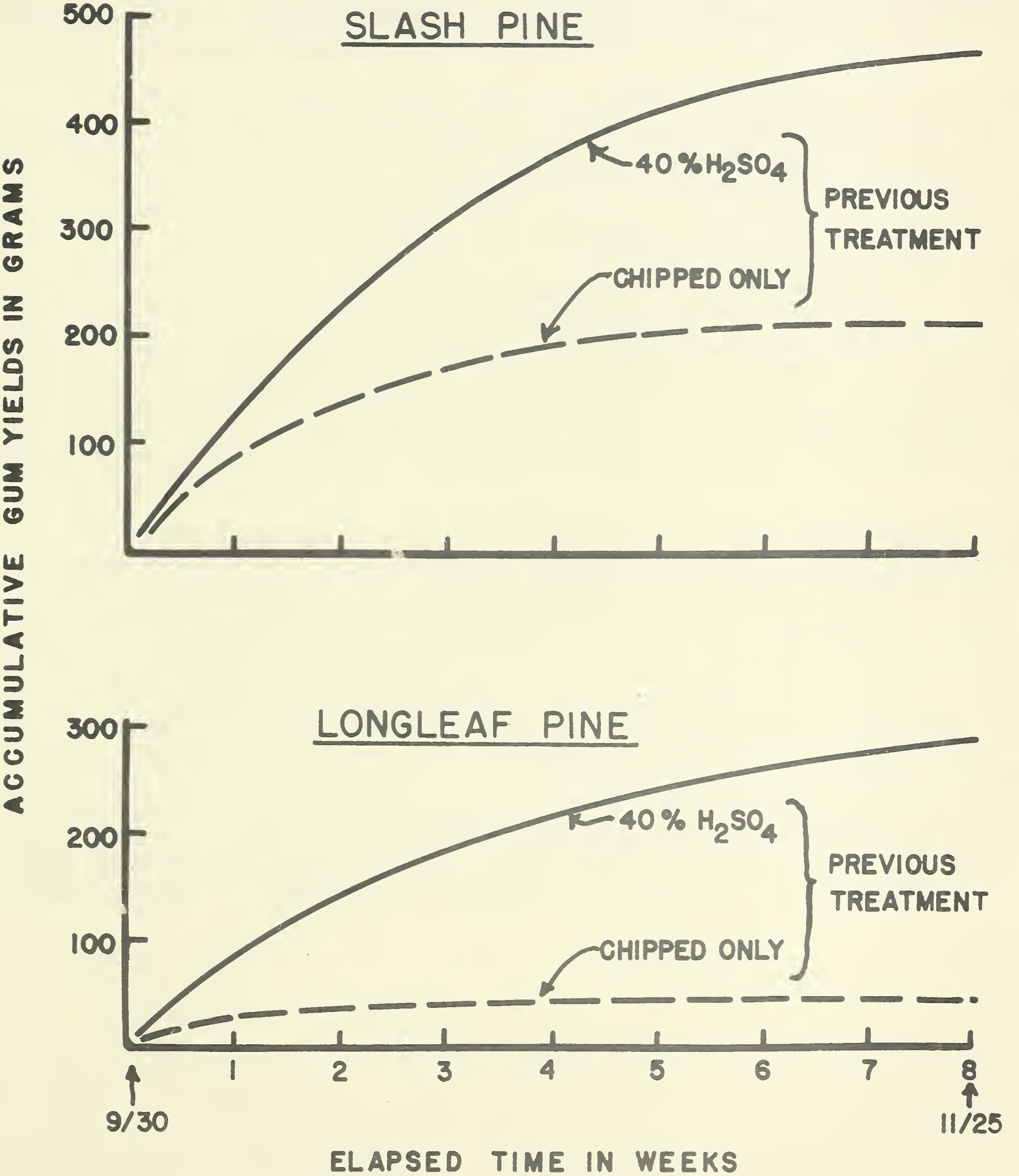


FIGURE NO. 5

COMPARATIVE WEEKLY GUM YIELDS FOLLOWING 4 CONSECUTIVE WEEKS OF CHIPPING & TREATMENT



Depth and Height of Chipping with Chemical Stimulation

Current accepted practice in height and depth of chipping is not static, but streaks about 1/2 inch in depth and 3/8 to 1/2 inch in height are the most commonly used. With chemical stimulation a need arose for a further study of variations in height and depth of chipping using different chemicals at different concentrations, and of the concurrent effect of frequency of chipping. Preliminary studies in 1942 led to the 1943 experiment on depth, height, and frequency of chipping summarized in tables 9 and 10.

Only tentative conclusions can be drawn from these results because in general only yields for 1 year are represented, and further desirable variations in height of chipping (with and without treatment) will not be available until later. However, a number of important relationships are indicated, with one particular treatment being outstanding.

Statistical analysis of the data for height of chipping, for all treatments combined, showed that the 1/4-inch height gave significantly less gum than either 1/2 or 3/4 inches, with no significant difference in yields between the two latter heights. Examination of individual treatment totals for the various heights reveals several interesting relationships, but these are mainly only trends and need further clarification that will be provided by current work. Treatment with sodium hydroxide on a weekly or biweekly schedule showed no definite trend differences (except for generally low yields for 1/4-inch height) for any of the variations in height and depth of chipping. A slight trend of small yield increases, with weekly or biweekly chipping and treatment with sulphuric acid, was indicated for the 3/4-inch height over 1/2-inch height chipping for all depths, but these increases were too small to be significant. Thus, on the basis of these experiments, chipping 1/2 inch in height appears to be the most efficient in terms of seasonal face height and maximum gum yields.

The most important outcome of these experiments was the revelation that bark chipping, which is the removal of the outer and inner bark tissues down to but not including the wood, combined with treatment with sulphuric acid, consistently gave greater yields than any other treatment combination used. Preliminary results in 1942 indicated that bark chipping 1/2 inch in height treated with 40-percent sulphuric acid consistently resulted in greater yields than regular acid-treated chipping 1/2 inch in depth and 1/2 inch in height. The experiments reported in tables 9 and 10 substantiated the preliminary conclusions, and these were further strengthened by the results of separate experiments indicated in table 8. All these formed the basis for the statements made in reporting a preliminary model of a tool designed especially for bark chipping (37). Continuation of these experiments, and more intensive current trials of height variations, will provide a more adequate basis for judging optimum heights of chipping with chemical treatment and bark chipping.

Table 9. - Yield results with variations in frequency, depth, and height of chipping using different chemical stimulants for the 1943 season with slash pine

Chemical treatment	Frequency of chipping*	BC** depth: 1/4 inch height	BC** depth: 1/2 inch height	BC** depth: 3/4 inch height	1/2 inch depth: 1/4 inch height	1/2 inch depth: 1/2 inch height	1/2 inch depth: 3/4 inch height	3/4 inch depth: 1/4 inch height	3/4 inch depth: 1/2 inch height	3/4 inch depth: 3/4 inch height
		Percent increase or decrease								
Untreated	Weekly	-32	- 8	-23	- 9	3999***	- 1	+ 9	+ 3	+ 5
25% NaOH	Weekly	- 2	+19	+26	+42	+33	+19	+ 4	+26	+10
40% H_2SO_4	Weekly	--	+29	+72	--	+40	+58	--	+44	+44
60% H_2SO_4	Weekly	--	+50	+54	--	+53	+15	--	+24	+63
25% NaOH	Biweekly	-53	-38	-31	-25	-38	-30	-40	-12	-38
40% H_2SO_4	Biweekly	--	- 8	+22	--	- 7	+ 9	--	- 9	-15
60% H_2SO_4	Biweekly	--	-27	+ 7	--	+20	- 7	--	- 1	+ 5

*Biweekly chipping refers to applying a streak every 2 weeks.
**Bark chipping - chipped through bark to wood.
***Average yield in grams for untreated control for 30 streaks (April 15 - November 4, 1943). All other figures indicate the percentage increase or decrease in yields compared with this as the control.

Table 10. - Yield results with variations in frequency, depth, and height of chipping using different chemical stimulants for the 1943 season with longleaf pine

Chemical treatment	Frequency of chipping*	BC** depth: 1/4 inch height	BC** depth: 1/2 inch height	BC** depth: 3/4 inch height	1/2 inch depth: 1/4 inch height	1/2 inch depth: 1/2 inch height	1/2 inch depth: 3/4 inch height	3/4 inch depth: 1/4 inch height	3/4 inch depth: 1/2 inch height	3/4 inch depth: 3/4 inch height
					Percent increase or decrease					
Untreated	Weekly	-33	- 5	-22	-21	2853***	+ 4	-21	-12	- 2
25% NaOH	Weekly	+10	+ 5	+23	+17	+10	+26	+ 8	+31	+45
40% H_2SO_4	Weekly	--	+44	+55	--	+ 6	+18	--	+56	+19
60% H_2SO_4	Weekly	--	+78	+64	--	+60	+49	--	+14	+53
25% NaOH	Biweekly	-38	-38	-38	-45	-39	-40	-42	-35	-39
40% H_2SO_4	Biweekly	--	+30	+ 9	--	-14	-20	--	-32	- 3
60% H_2SO_4	Biweekly	--	+13	+16	--	- 9	- 6	--	- 9	- 6

*Biweekly chipping refers to applying a streak every 2 weeks.
**Bark chipping - chipped through bark to wood.
***Average yield in grams for untreated control for 30 streaks (April 23 - November 12, 1943). All other figures indicate the percentage increase or decrease in yields compared with this as the control.

Effective Treatment Period

An important factor directly concerned with the continued successful and profitable use of chemical stimulants in successive years of working is the effective treatment period. This may be defined as that period during which a given chemical treatment and chipping schedule will result in maximum gum yields consistent with the effort expended. The two most important features affecting this period are the intensity and duration of chemical treatment.

The magnitude of the extra gum yield associated with the application of a chemical stimulant increases as the season advances (fig. 6). Studies of seasonal trends based on weekly chipping with acid treatment indicate that increased yields due to applied chemicals reach a maximum a little past mid-season. A sharp decline in effectiveness of applied chemicals begins to occur after about 20 treated streaks, and eventually reaches a point at which no significant yield increases are obtained. This pertains particularly to the more intensive treatments such as weekly chipping with acid. Thus there is a period of as much as 10 weeks at the end of the season when little or no extra gum yield is obtained due to applied chemicals. The length of this period may vary because of a number of circumstances which include the time chipping and treatment starts in the spring, the number of treated streaks, the intensity of treatment, and seasonal variations.

When chipping and treatment are started in late spring and early summer, the decline in increased gum production usually comes later in the year, but in any event occurs several weeks before the end of the season. The number of treated streaks probably plays the biggest role here in that the more treated streaks put on before the time of the natural seasonal decline, the sooner the reduction in the magnitude of yield increases. The converse is also true. The fewer treated streaks each tree receives before reaching the usual point of diminishing gum yields, the more prolonged is the period of increased gum flow. Intensity of treatment, however, may modify this trend, since usually the more intensive treatments, although resulting in maximum gum production, have a shorter effective treatment period. Weekly chipping with acid treatment falls in this latter category. A less intensive treatment is the "skip" schedule with weekly chipping and acid treatment of every other streak. The use of stronger acid concentrations and complete thoroughness of application would also contribute to a more intensive treatment and tend to shorten the effective treatment period. Weather conditions which change the usual seasonal trends also probably influence the length of the period in which applied chemicals are effective.

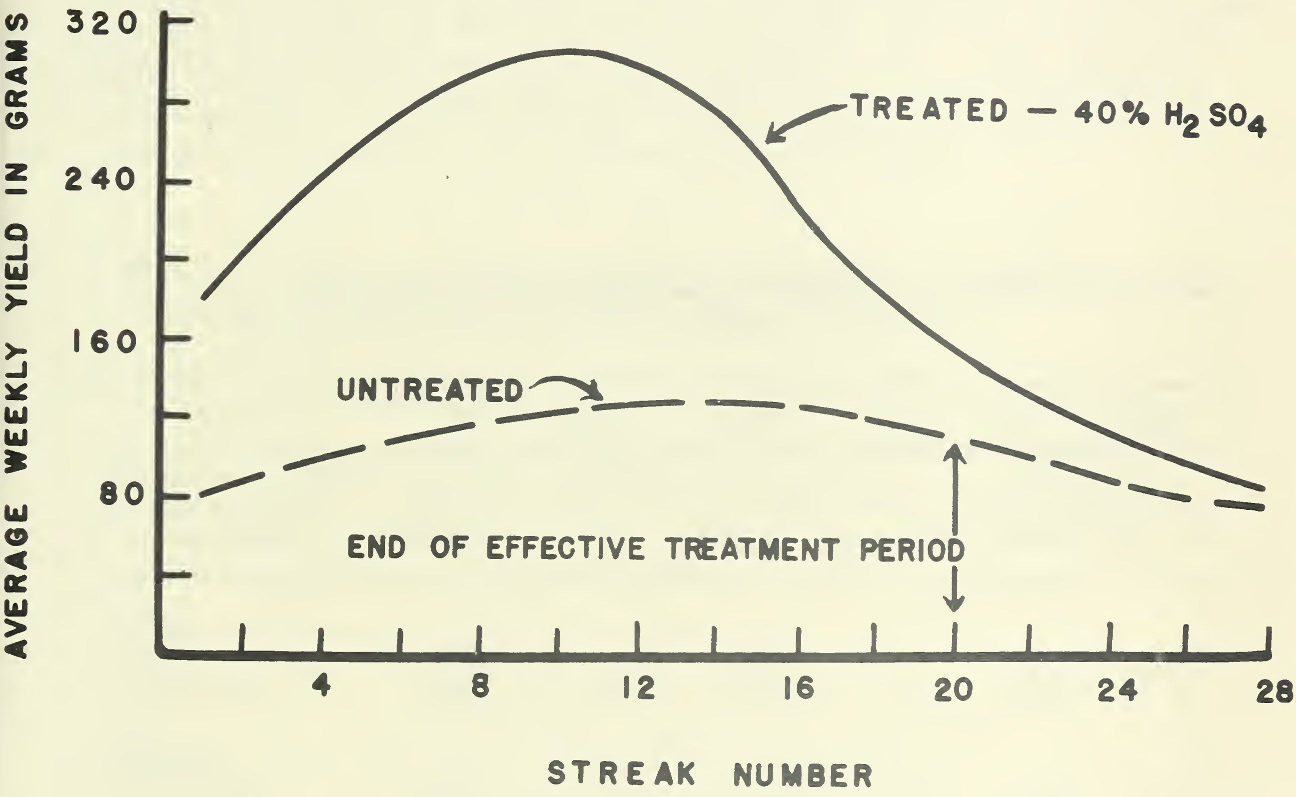
Intensive treatments, besides their influence on the end of the effective treatment period, also affect the results at the beginning of the next season's work. For instance, if the intensity of the previous season's chemical treatment has been high, then the yields of the first few treated streaks generally will not be above those of the untreated streaks. Most factors affecting the duration of effective treatment period also affect the number of initial unproductive treated streaks put on in the spring. Several possible factors are concerned in this "carry-over" result, and fortunately a procedure is available to reduce this unproductive initial period.

FIGURE NO. 6

SEASONAL TRENDS IN AVERAGE WEEKLY GUM YIELDS

FROM TREATED AND UNTREATED TREES

SLASH PINE



The trees in the experiment reported in table 5 received, for the first time, three untreated weekly chippings at the end of the 1943 season. This resulted in the removal of most of the wood seriously affected by acid treatment during 1943. It is significant that the first four treated streaks in 1944 receiving the 40-percent sulphuric acid showed a large increase in yield. This was the first time this had occurred, as the first three or four treated streaks in 1942 and 1943 showed little or no stimulation in gum yield. Other experiments, in which untreated streaks were put on at the end of the 1943 season, also showed the same response in the spring of 1944.

The results of an extreme in intensity of chemical treatment are summarized in table 11. In this experiment chemical treatments were started in April 1942, and continued without the usual winter rest period until August of the next year. During the regular chipping season a substantial yield increase of 63 percent was obtained. Continued treatment during the winter and the first portion of the next season showed an actual decrease in yields from the treated streaks. The effective treatment period for the first season for weekly acid treatment extended from April through September, with an average increase of 70 percent for this period. This is in contrast to only 63 percent when based on a normal season's results. From September 1942, through August 1943, none of the treated streaks gave significantly more gum than the untreated streaks. This illustrates the detrimental effect of the wrong use of an intensive chemical treatment.

Table 11. - Yield results for continuous chipping and treatment for a total of 70 streaks (April 1942 to August 1943) for slash pine

Period	First season 4/12 - 11/23/42		Winter season 11/23/42 - 4/12/43		Second season 4/12 - 8/16/43	
Chipping frequency and chemical treatment	Average yield in grams	Percent increase or decrease	Average yield in grams	Percent decrease	Average yield in grams	Percent decrease
Weekly						
Untreated	2847	--	1301	--	2153	--
40% H_2SO_4	4048	+63	1126	-13	2110	- 2
Biweekly						
Untreated	1374	-45	--	--	--	--
40% H_2SO_4	3026	+22	1150	-12	1688	-22
Delayed acid*	2201	-12	--	--	--	--

*Chipping every other week, with acid applied 1 week after chipping.

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

A treatment of moderate intensity, such as 20-percent sulphuric acid applied to weekly chipping, does not appreciably decrease in effectiveness from year to year (table 5). Another conservative treatment, given for only the last half of the first season, and illustrated by the 40-percent sulphuric acid skip treatment summarized in table 6, shows little or no decrease the second year in its stimulating effect. The increased yields during the effective treatment periods for this latter treatment were respectively 48 and 52 percent for the 1942 and 1943 seasons.

It is thus evident from all results to date that, in general, not only is the continued use of some chemical treatments beyond the effective treatment period economically unsound, but an actual decrease in yields can be expected in successive years of treatment, particularly when intensive acid treatments are used. To avoid this difficulty two alternatives are possible. First, intensive acid treatments can be stopped, but chipping continued, at the end of the effective treatment period. Second, less intensive acid treatments may be continued somewhat longer but in no event past the effective treatment period. Preliminary results consistently show that the addition of a minimum of about 4 or 6 untreated streaks after treatments stop in the fall will reduce or eliminate the first unproductive treated streaks put on the following spring. This procedure should invariably be applied to both the alternatives mentioned above.

Effect of Chemical Stimulants on the Trees

One question frequently raised by those interested in using chemical stimulants concerns the effect on the health and future productive capacity of the tree. An effective answer is provided in the fact that no tree in our experiments has ever been killed through chemical treatment, and most important, trees that are now in their fourth year of treatment are still producing more gum than those not treated.

A comprehensive study of the effects of chemical stimulants on trees has been underway since the initiation of intensive work early in 1942. The first report (41), dealing with resin soaking and crown appearance, was based in part on trees which are now in their fourth year of treatment. The authors found that "No serious injury resulting from chemical treatment has been noted either on trees in the controlled experiments at Olustee, Florida, or on trees in those commercial-scale tests in Georgia and Florida which were carefully examined." They also specifically state that ". . .(1) The red lightwood condition induced in acid-treated faces is not dry face, and does not develop into dry face although dry face may occasionally be found in such trees just as it is in untreated trees. (2) On the basis of crown appearance it seems to be impossible, after 3 full seasons of working, to distinguish acid-treated trees from trees that have been chipped without treatment."

Conclusions from the earliest work reported in Germany by Kublun (17) mentions that "No damage to trees was found after a full season's work." Hessenland (13) reports that in the 1935 experiments using over 8000 faces, "Damage to the trees has not been observed so far." In his 1938 report Loycke (24) states that Splitter in 1936 found that "The effectiveness of the stimulant is not diministed when the tree is treated for a number of years." No statements were made by Russian workers (in the available literature) as to the effect of chemical stimulants on the tree.

Results of portions of other experiments performed at this station indirectly support the conclusion that no serious permanent harm is done to the tree by chemical stimulants. One example is furnished by the preliminary multiple-cup experiments using as many as nine acid-treated faces per tree. In this instance enormous yields of gum were obtained from single trees over a portion of the season, amounting to many times the yields usually obtained from single trees in that period. In spite of this large drain on the tree's reserves, and the lack of any uninterrupted bark bars, these trees are still alive 1 year later although growing much slower. In another instance about four quarts of 40-percent sulphuric acid per tree were taken up during the season from shields placed around freshly cut streaks. Although considerably more gum was dipped from these trees than is usually obtained in one season, no harm was done to the trees from the standpoint of impairing further gum yields or causing any apparent injury. The use of concentrated sulphuric acid also appeared to result in no damage to the tree, although it necessitated the removal of more wood per streak after a period of treatment; this treatment is not recommended for use in any event.

This experience, combined with the abundant evidence obtained in previous experiments here and abroad, makes it possible to state conclusively that no apparent permanent injury to the tree results from the use of chemical stimulants to increase gum yields.

Effect of Chemicals on Gum and Its Constituents

Comparative tests on gum grades and relative amounts of turpentine and rosin were begun with the inception of the use of chemicals in stimulating yields, both in this country and in Europe. The consensus is summarized in a recent report (29): "From results of the tests made so far, there appears to be no reason for not using acid or caustic soda stimulation as far as rosin grades and yields of turpentine and rosin are concerned."

Early Russian and German workers made essentially the same statement, but qualified it by saying that when excessive quantities of the chemicals were present in the original gum samples, differences were noted in some of the physical properties and chemical constituents of the gum, and in the products of distillation. These findings have been well summarized by Hessenland (14) and Sandermann (33). They point out certain disadvantages obtaining for specific rosin uses when excess hydrochloric acid is present in the gum. According to these authors, however, these disadvantages are not evident when modern gum-cleaning processes are used during distillation procedures, or when care is originally taken to avoid excess acid in the gum. This latter can be done by care in treating with proper applicators such as well-controlled sprays; "painting" on the chemicals with brushes or swabs is not the best procedure because of the danger of excess acid in the gum caused by dripping. Also, greater yields were obtained with sprays (39).

Comprehensive studies of the effects of chemical stimulation on gum grades, and the yields of turpentine and rosin and their chemical and physical characteristics, were begun early in 1943 by the Naval Stores Division of the Bureau of Agricultural and Industrial Chemistry in cooperation with the Forest Service. A preliminary report (29) covers only a portion of this study, which is being continued in 1944. It was found that cloudy rosin is sometimes

obtained from gum from acid-treated trees when processed on a fire still. However, as Mitchell (25) points out, "According to present information rosin grades are unaffected by chemical stimulation if the gum from treated trees is either blended or properly cleaned in processing."

Large-Scale Tests of Chemical Stimulants

Shortly after the success of the initial 1933 experiments in Germany (12), trials were made on a much larger number of Scotch pines. Hessenland (13) mentioned a total of over 8500 trees in the 1935 tests, with considerable yield increases being obtained with 25-percent hydrochloric acid. The 1937 tests described by Loycke (24) included over 350,000 trees about equally divided between three separate areas. Yield increases for the three areas were 208, 265, and 250 percent. He concluded that "The results of earlier smaller-scale studies by Hessenland, Kublun, and Splitter apply equally well to other forest and climatic conditions, and on a large commercial scale."

Acid stimulation tests (3), conducted under the 1942 Naval Stores Conservation Program on about 72,000 trees on 17 different operations, showed yield results varying from a decrease of 9 percent to an increase of 38 percent. Investigations showed that the poorer results obtained on some acid test areas could almost always be traced to poor workmanship in regularity of chipping and adequacy of chemical treatment.

Dorman (5) reports that in 1943 a total of 13 out of 14 commercial operations keeping careful records on a total of approximately 90,000 trees obtained substantial yield increases by the use of chemical stimulants. There were nine operations that showed increased net profits from stands receiving chemical treatments. Frequent inspections and analysis of all factors concerned indicated that increased yields were directly correlated with the quality of workmanship, since sufficient quantities of the chemical adequately applied to regularly chipped streaks resulted in material increases.

The potential and actual profits to be derived from commercial operations have been discussed by Mitchell and Dorman (26). They summarize the results of the 1942 tests and present a comprehensive discussion of the economics of chemical stimulation.

Physiological and Anatomical Studies

Although European workers have studied the physiological processes involved in gum exudation (2, 15, 16, 28, 43), and the attendant increases in flow with chemical stimulation (1, 23, 30, 42), there is little agreement as to the exact chemical, physical, and anatomical conditions that exist. This confusion is probably natural in that relatively little basic physiological and anatomical work has been done on oleoresin formation, transport, and exudation alone, without the complications of chemical treatment. The work of Münch (28) is most widely quoted, but other workers have made equally important contributions. Space is not available here to summarize the work that has been done, but moderately comprehensive summaries are available (7, 35, 40). The simplest published explanation has been made by Hall et al (8, 9, 10) who briefly present a picture of some physiological factors concerned with oleoresin production. This is far from a complete resumé of the internal phases that are concerned, but serves as an introduction to the complicated pattern we have only glimpsed.

Most investigators are of the opinion that chemicals influence gum flow in pines by bringing about numerous synchronized physiological and anatomical changes. These changes involve, among other things: (1) increasing the effectiveness of the radial system of resin ducts; (2) keeping gum passages open for longer periods of time; (3) maintaining gum in a more fluid state by retarding crystallization internally; and (4) increases in metabolic level—the formation or synthesis of precursors and oleoresin itself.

Several valuable leads, from the standpoint of practical application, resulted from early fundamental studies of chemical stimulants in naval stores at this station. One of these, the effect on yields of deep gutter insertions using a broadax (36), was an outgrowth of studies designed to delimit the source of the extra gum obtained from chemical stimulation. Another, stemming from other portions of the same study, was the initial use of bark chipping on slash and longleaf pines (37). The synergic effect of added arsenic (38) and of phosphorous was first found in studies of the effects of various classes of chemical compounds on gum yields.

SUMMARY

This paper is devoted primarily to the presentation of the results of experimental work on chemical stimulation of gum flow performed in 1942 and 1943 on the Olustee Experimental Forest, Lake City, Fla., with major emphasis placed on those phases which were important as the basis for the 1943 and 1944 recommendations. No attempt is made to summarize all the work previously published, but pertinent papers and historical background are described briefly.

The following brief statements summarize the more important findings of the experimental work of 1942 and 1943:

1. Consistently greater yield increases have been obtained with sulphuric and hydrochloric acids than with any other single chemical used.

2. Still further yield increases have resulted from treatments with chemical combinations of sulphuric acid with such substances as sodium arsenite, potassium phosphate, and potassium aluminum sulphate.

3. After a consideration of all factors, the most effective concentration of sulphuric acid for treating slash pine was found to be 40 percent, with 60 percent the best for longleaf pine. Adequate chemical application was found to be almost as important as concentration, with yield increases up to 121 percent being obtained with careful treatment.

4. Greatest yields were obtained from weekly chipping with acid treatment. Under conditions of labor shortages necessitating less frequent chipping, however, greatest yields can be obtained by applying acid each time a tree is chipped. A skip treatment, in which weekly chipping is combined with acid treatment every other week, also showed considerable promise as a method to obtain increased gum yields.

5. The most outstanding result of the studies of the effects of different depths and heights of chipping combined with chemical treatment was the increased yields associated with bark chipping. It was found that taking off only the bark down to but not including the wood, and treating with acid, gave greater yields than acid applied to any streak cut into the wood.

6. Weekly yield records of treated and untreated trees indicated that after about 20 streaks the increased yields associated with the more intensive chemical treatments usually decline. Continued chipping without chemical treatment for the remainder of the year is economically sound and leaves the trees in better condition to respond to chemical treatments the following season.

7. All studies combined, both here and in Europe, indicated conclusively that no apparent permanent injury to the tree results from the use of chemical stimulants to increase gum yields.

8. There appears to be no reason for not using acid stimulation as far as rosin grades and yields of turpentine are concerned.

9. Large-scale tests made on more than 30 commercial operations showed that greatly augmented yields may be obtained under optimum conditions of chemical treatments, and that acid treatment is economically feasible.

10. Although many of the fundamental physiological and anatomical responses and conditions associated with chemical stimulation are known, no single adequate explanation covering all phases of the complex reactions can be formulated at this time.

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